

Fourth Annual Conference on Carbon Capture & Sequestration

*Developing Potential Paths Forward Based on the
Knowledge, Science and Experience to Date*

IEA GHG Weyburn CO₂ Monitoring and Storage Project: An International Collaborative Research Program Led by the
PTRC Based in Regina, Saskatchewan, Canada



Weyburn Project Research Activities

A MECHANICAL EARTH MODEL FOR THE WEYBURN CO₂ MONITORING AND STORAGE PROJECT

Rick Chalaturnyk, PhD, PEng

Geological Storage Research Group, University of Alberta



May 2-5, 2005, Hilton Alexandria Mark Center, Alexandria Virginia



Fourth Annual Conference on Carbon Capture & Sequestration

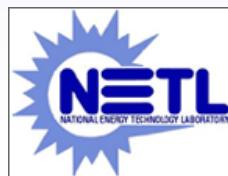
*Developing Potential Paths Forward Based on the
Knowledge, Science and Experience to Date*

Session 4B: Weyburn Project

Prediction of CO₂ Distribution and Storage Performance in Weyburn EOR Patterns with Different CO₂ Injection Strategies

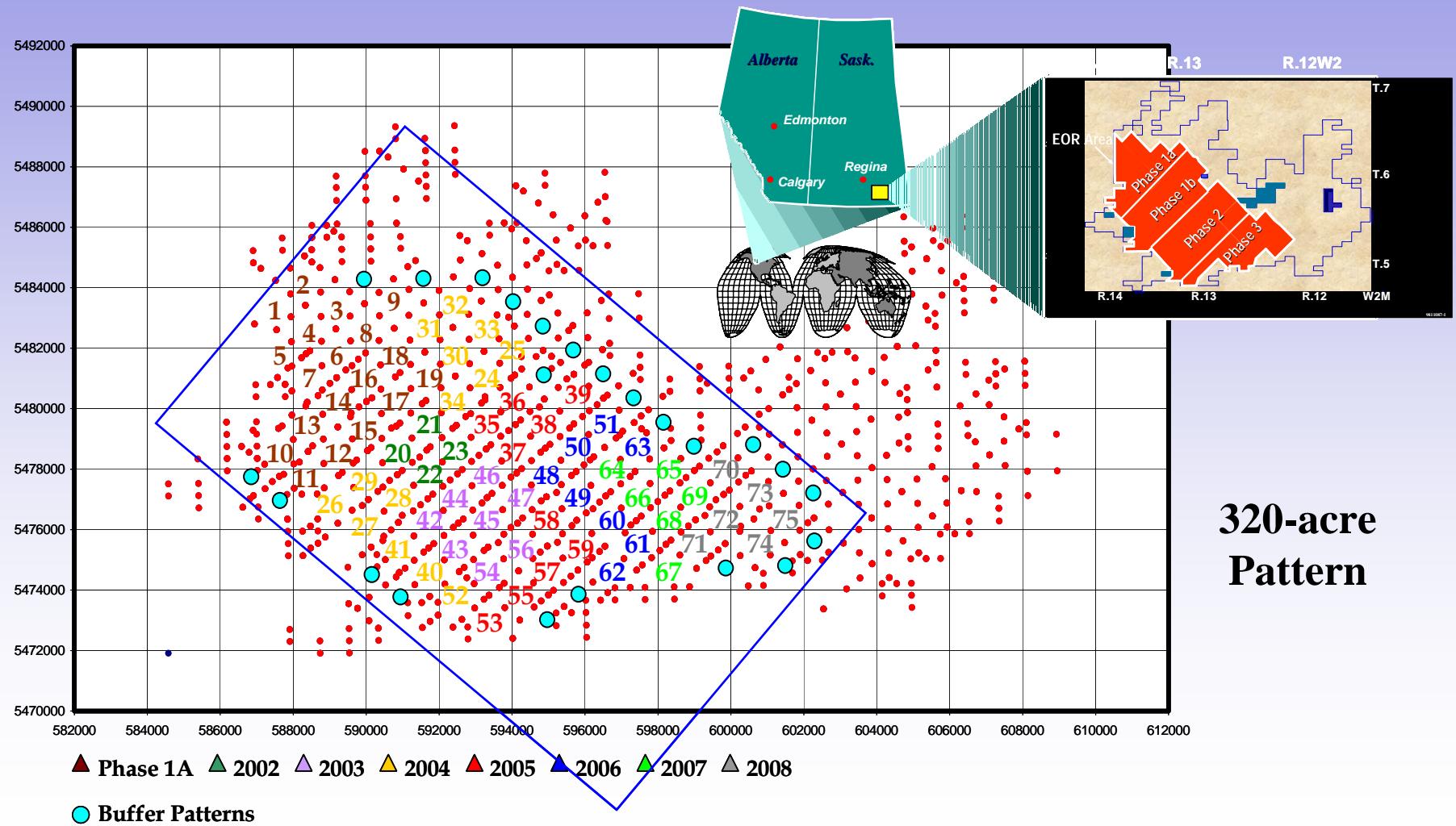
David H.-S. Law
Alberta Research Council (ARC)
Edmonton, Alberta Canada

May 2-5, 2005, Hilton Alexandria Mark Center, Alexandria Virginia



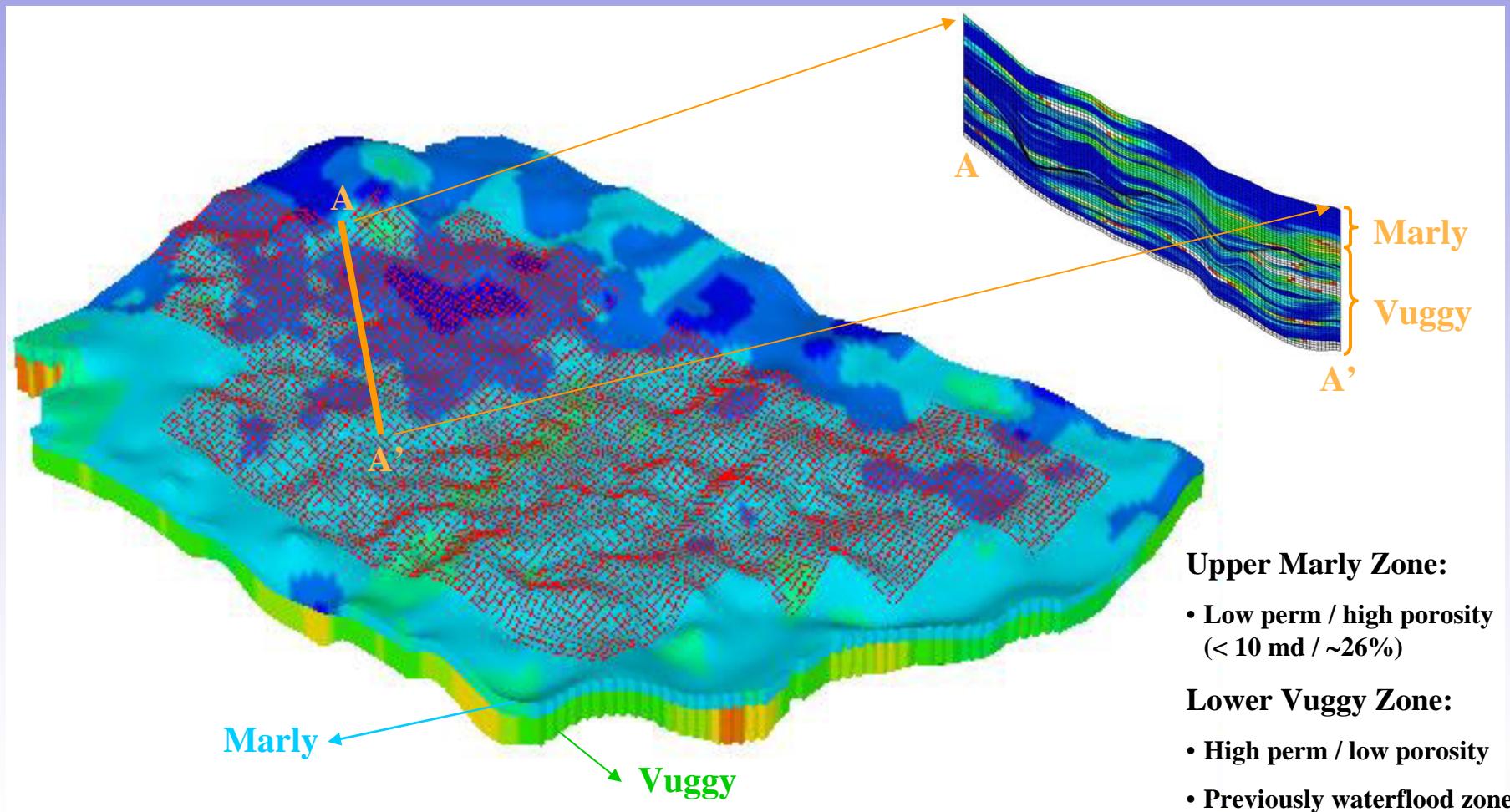
Weyburn EOR Area

75 Patterns Rollout Plan



Weyburn EOR Area

75 Patterns

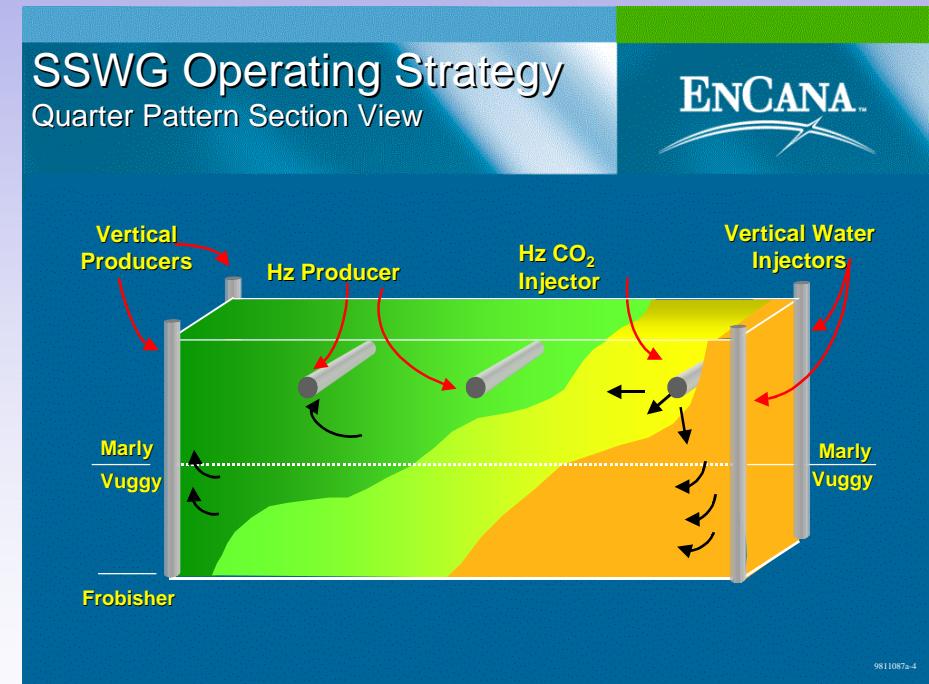
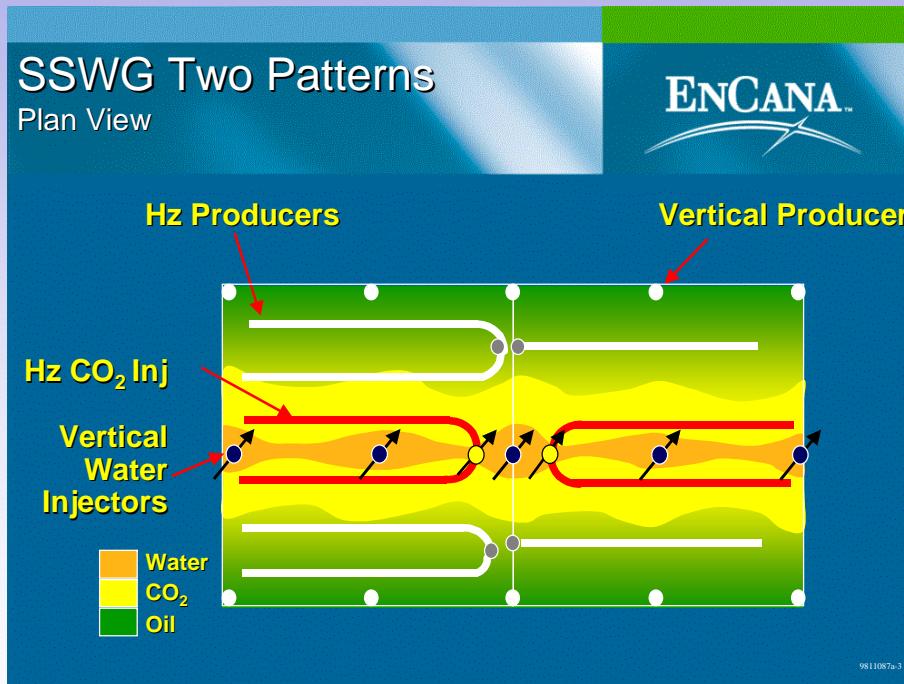


CO₂ Injection Strategies

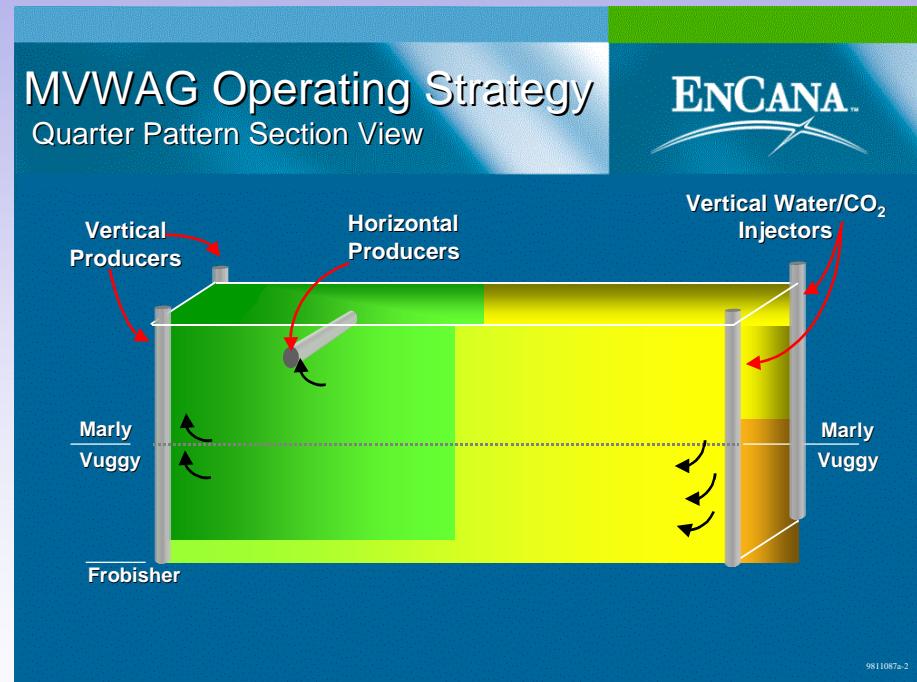
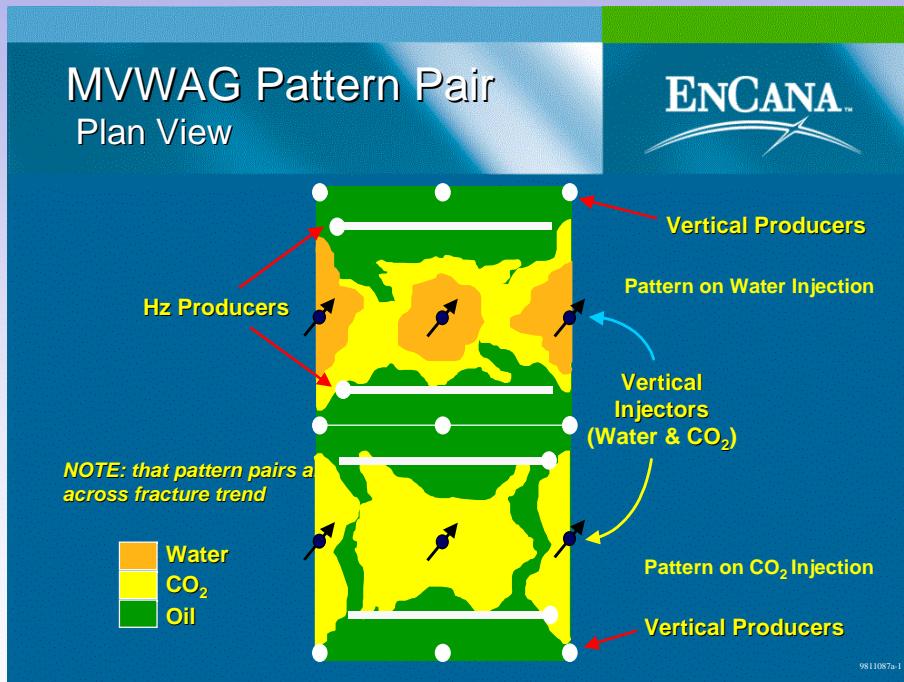
- Simultaneous but separate water and gas injection (**SSWG**)
- Vuggy water-alternating-gas (**VWAG**)
- Marly, Vuggy water-alternating-gas (**MVWAG**)
- Straight gas injection (**SGI**)

Tuned to varying geological characteristics
in different parts of Weyburn field

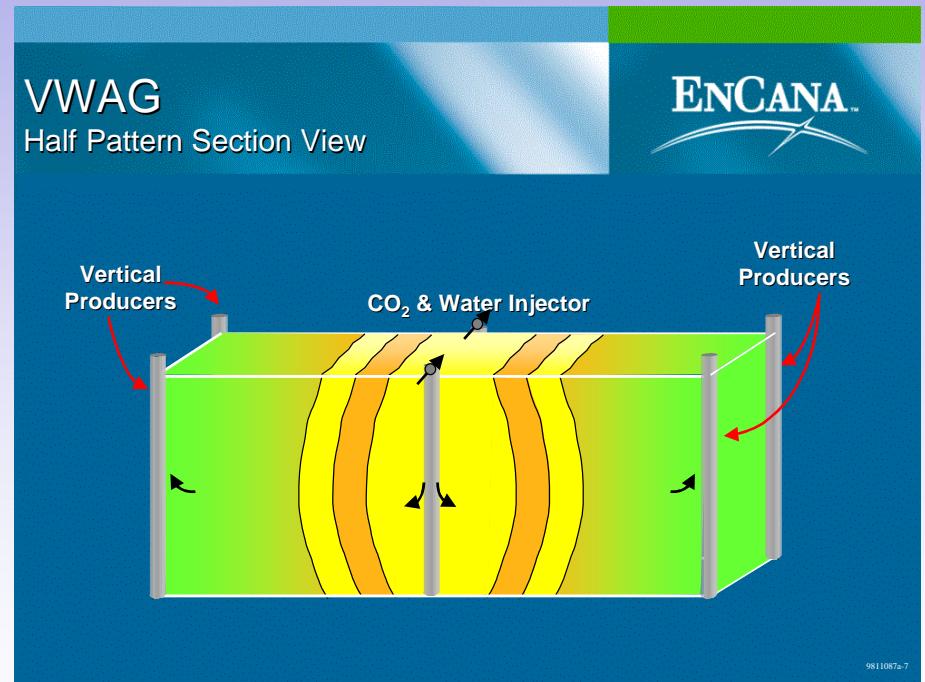
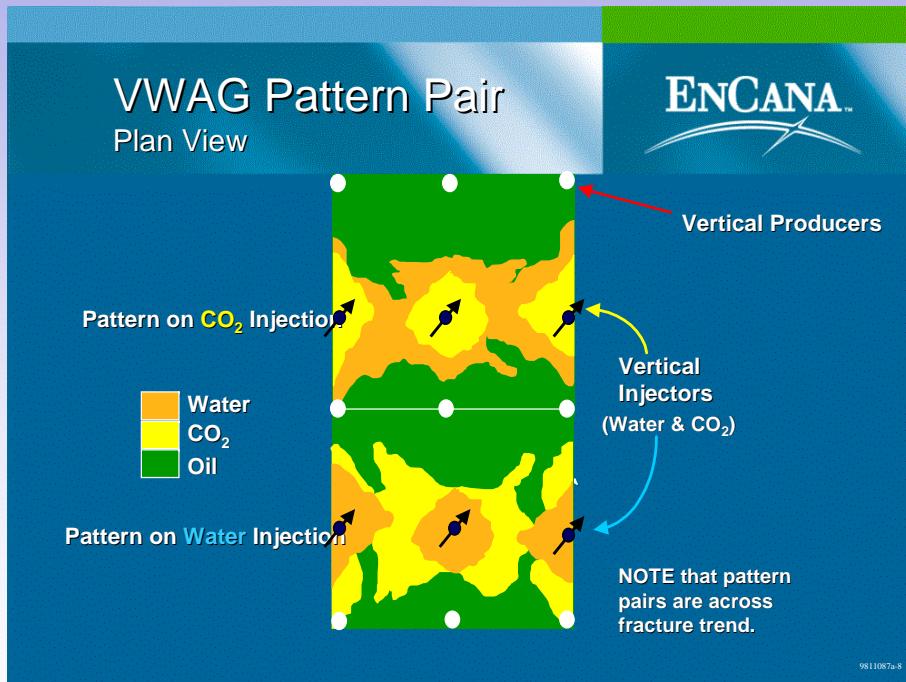
SSWG Injection Strategy



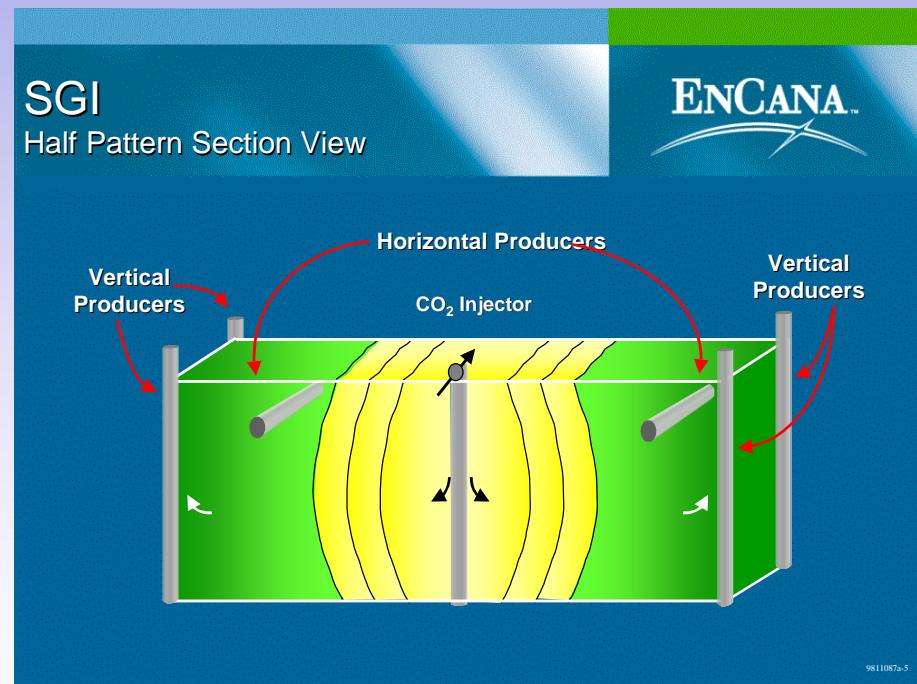
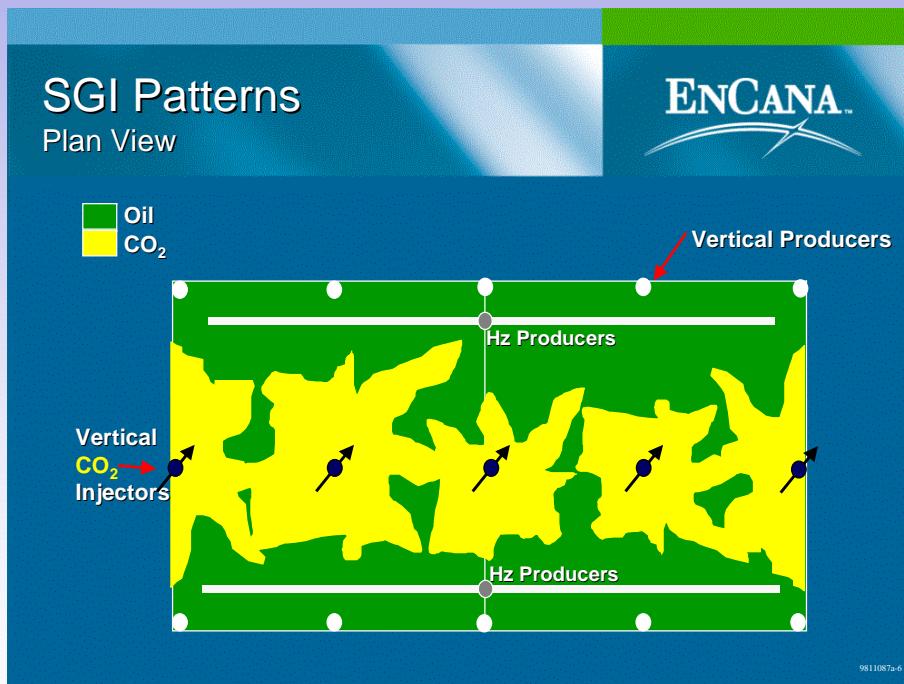
VWAG Injection Strategy



MVWAG Injection Strategy

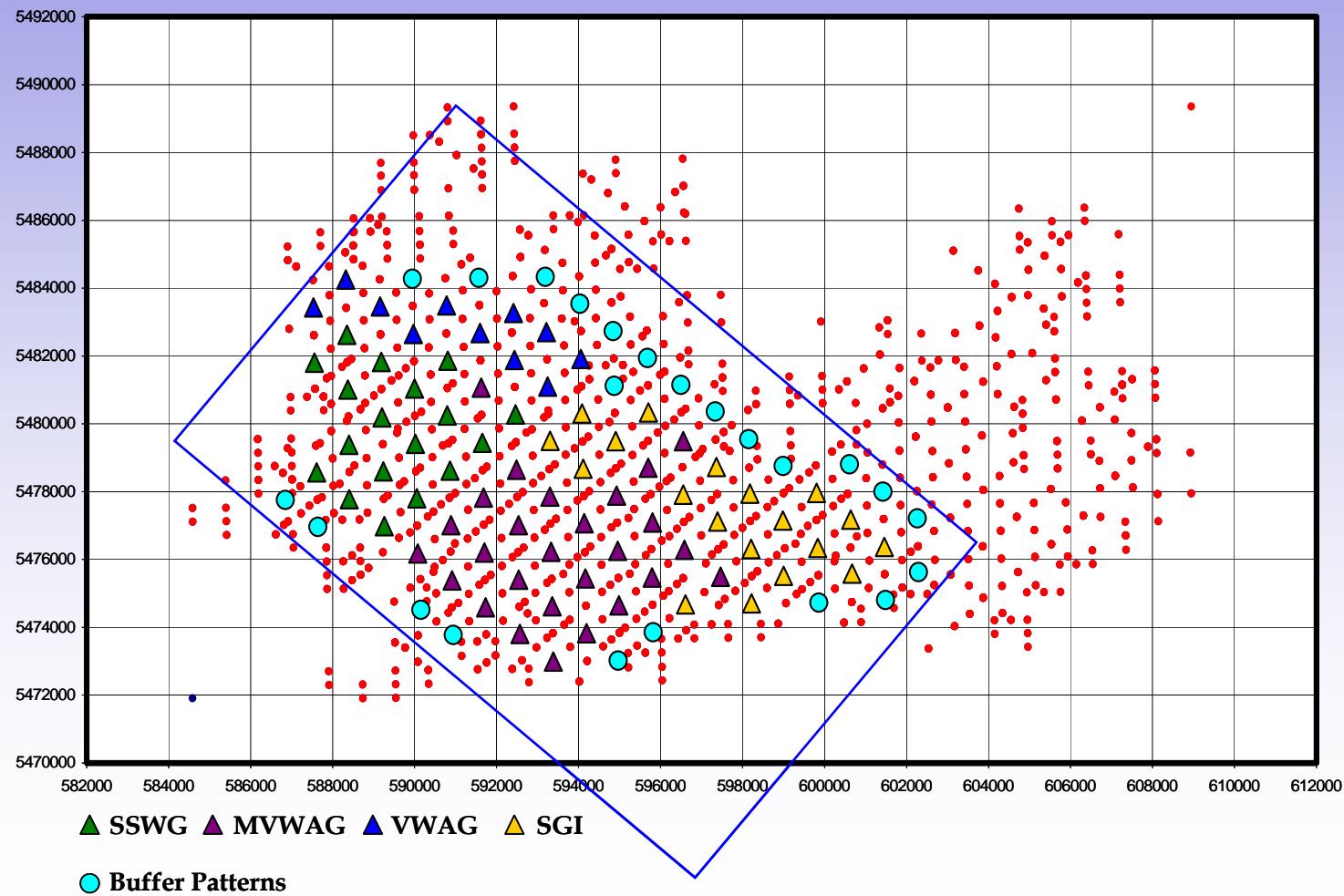


SGI Injection Strategy

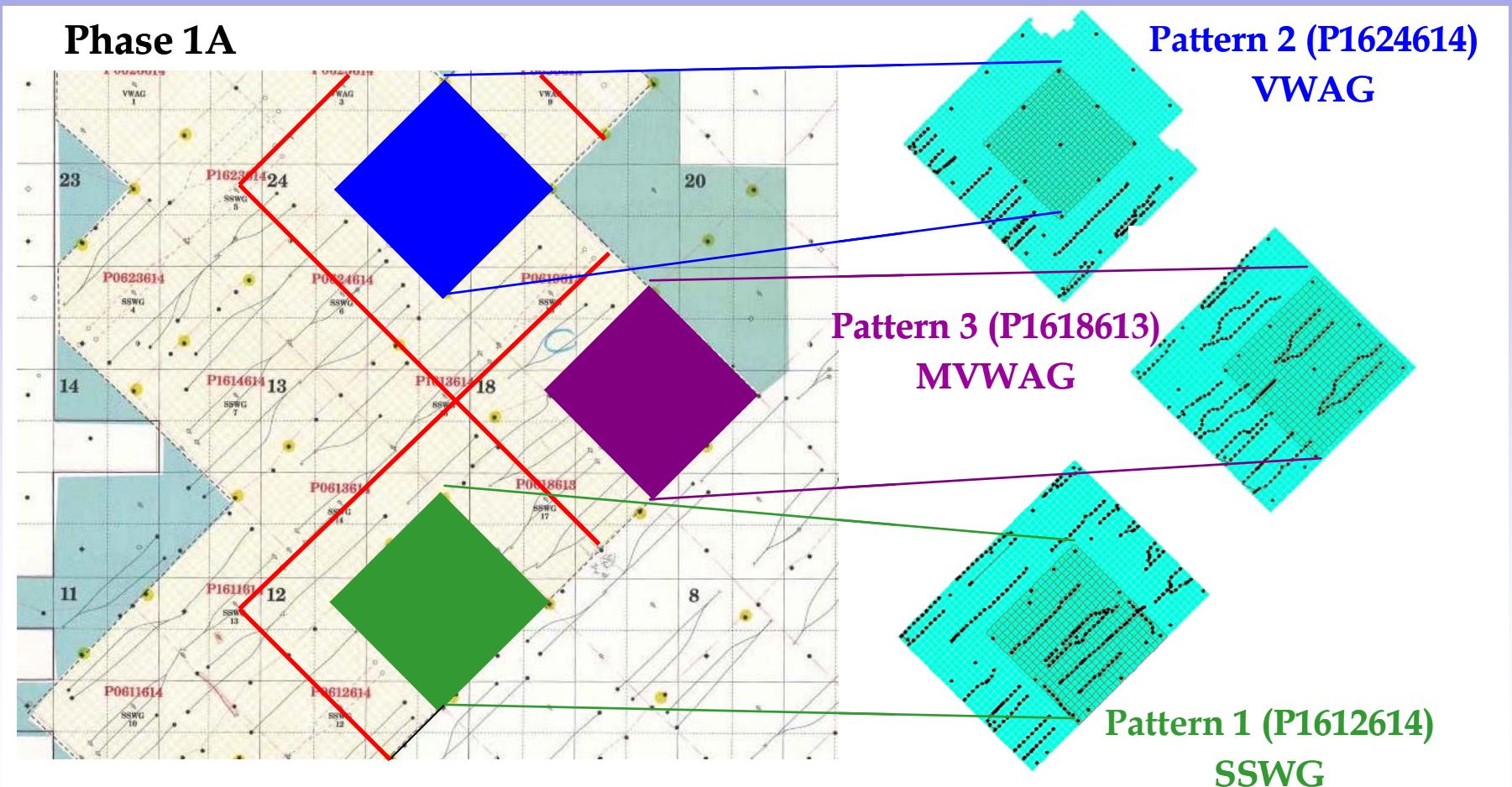


CO₂ Injection Strategies

75 EOR Patterns

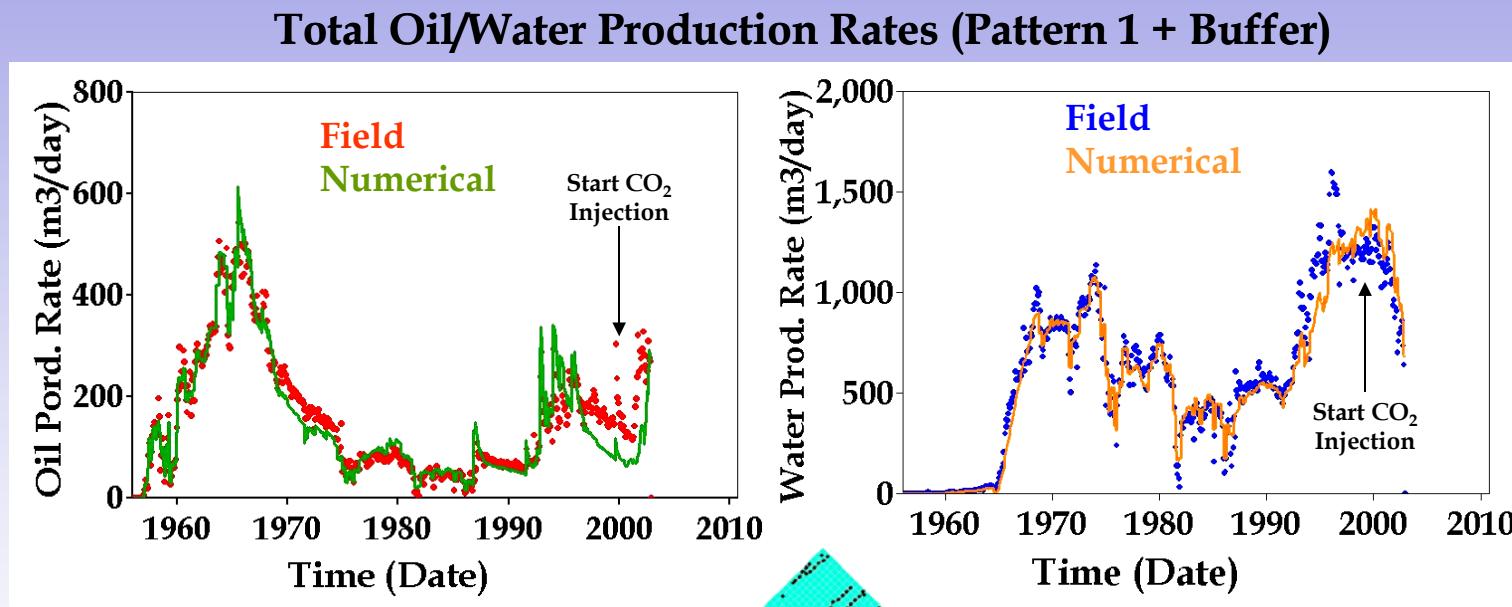


Single-Pattern Simulation

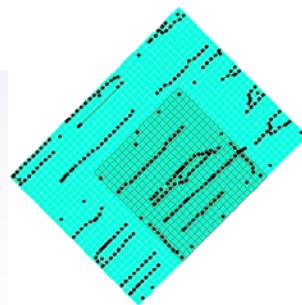


Model Validation

History Match Field Production Data (SSWG)

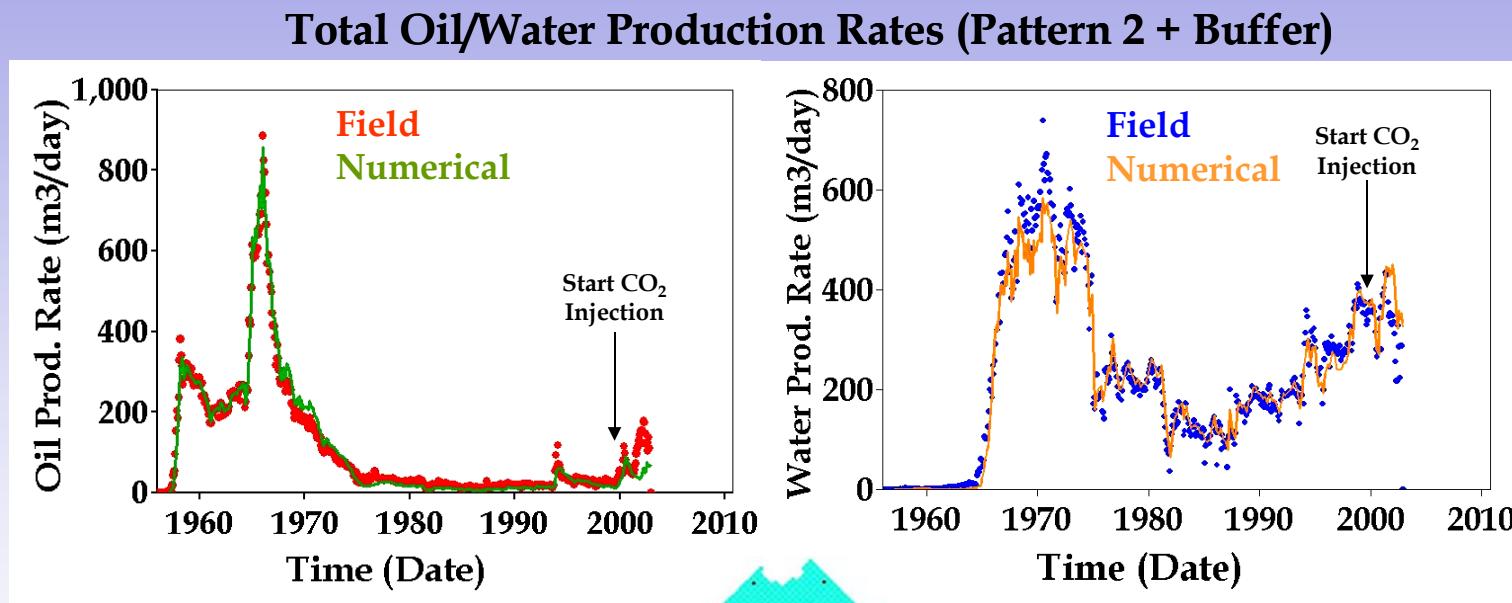


Primary: 1956 – 1964
Waterflood: 1964 – 2000
 CO_2 -flood: 2000 – 2002

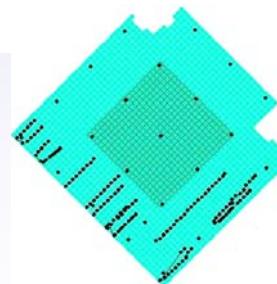


Model Validation

History Match Field Production Data (VWAG)

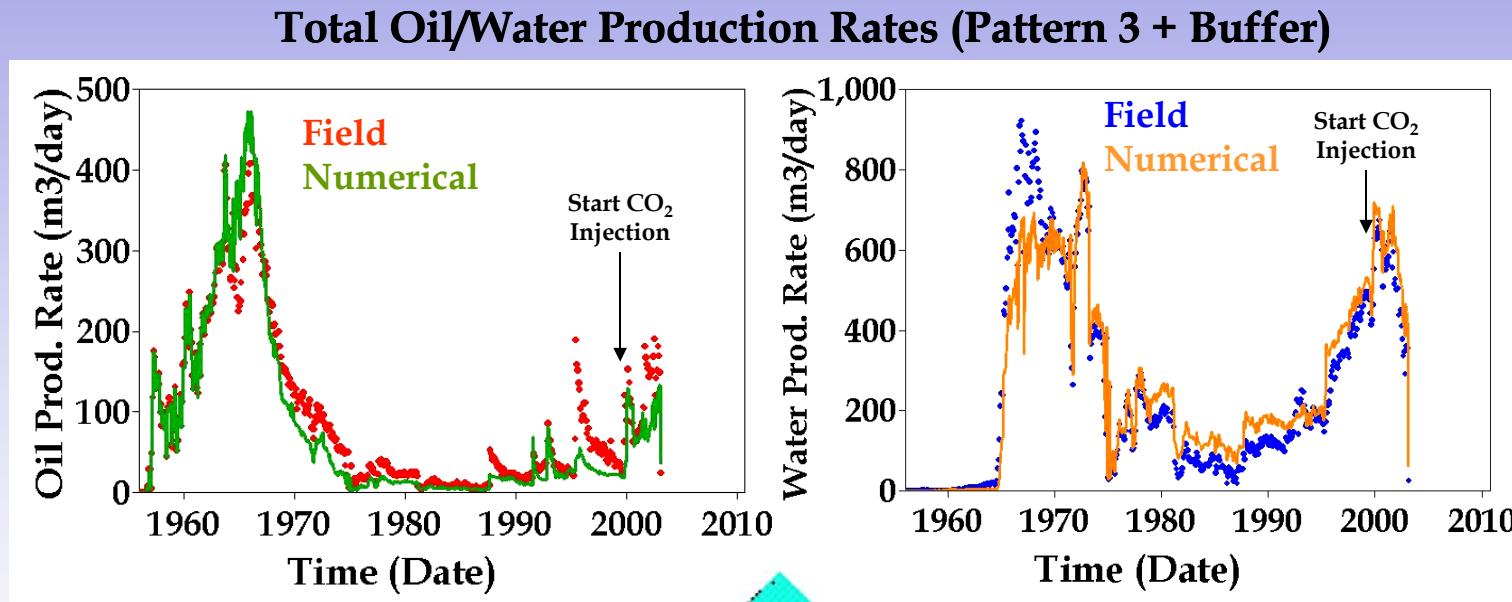


Primary: 1956 – 1964
Waterflood: 1964 – 2000
CO₂-flood: 2000 – 2002

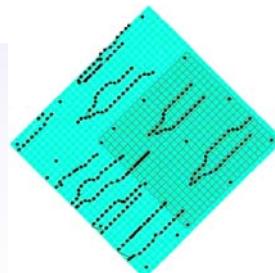


Model Validation

History Match Field Production Data (MVWAG)



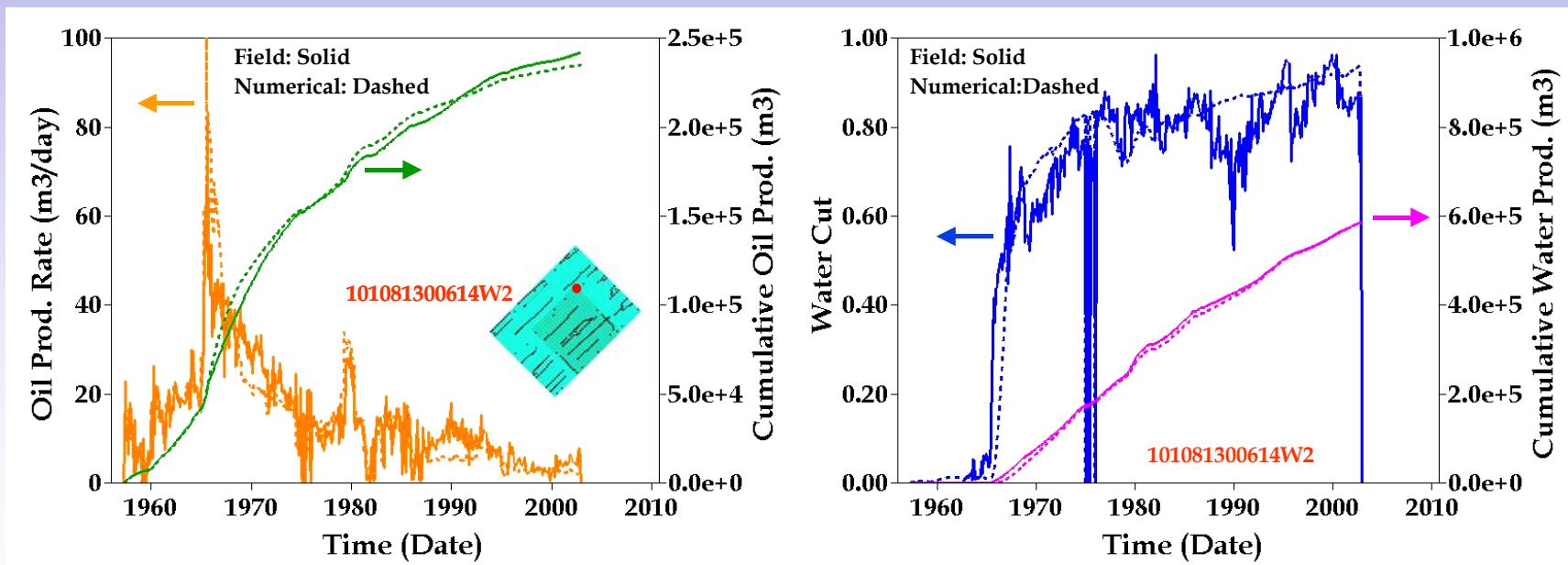
Primary: 1956 – 1964
Waterflood: 1964 – 2000
CO₂-flood: 2000 – 2002



Model Validation

History Match Field Production Data (SSWG)

Oil/Water Production (Individual Well: 101/08-13-006-14W2)



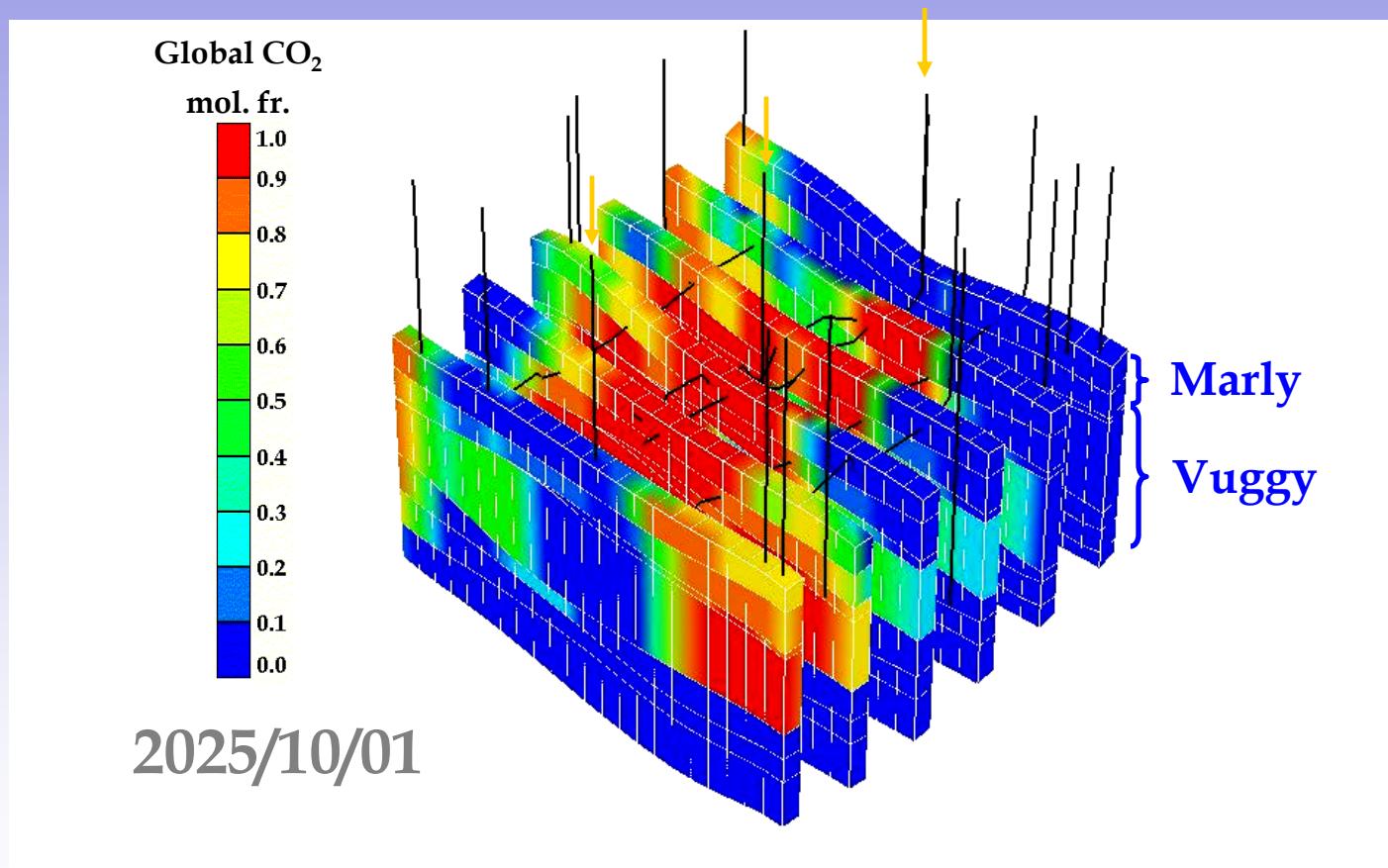
Numerical Prediction

CO₂-EOR / Storage Cases

Followed EnCana's CO₂ injection guidelines

- Case I: no GOR control at producers
- Case II: stopped gas injection after ~50% hydrocarbon pore volume (HCPV) CO₂ injection and continue with water only injection
- Case III: with GOR control at producers
 - Vertical producers shut-in when GOR > 2,000 m³/m³
 - Horizontal producers shut-in when GOR > 4,000 m³/m³

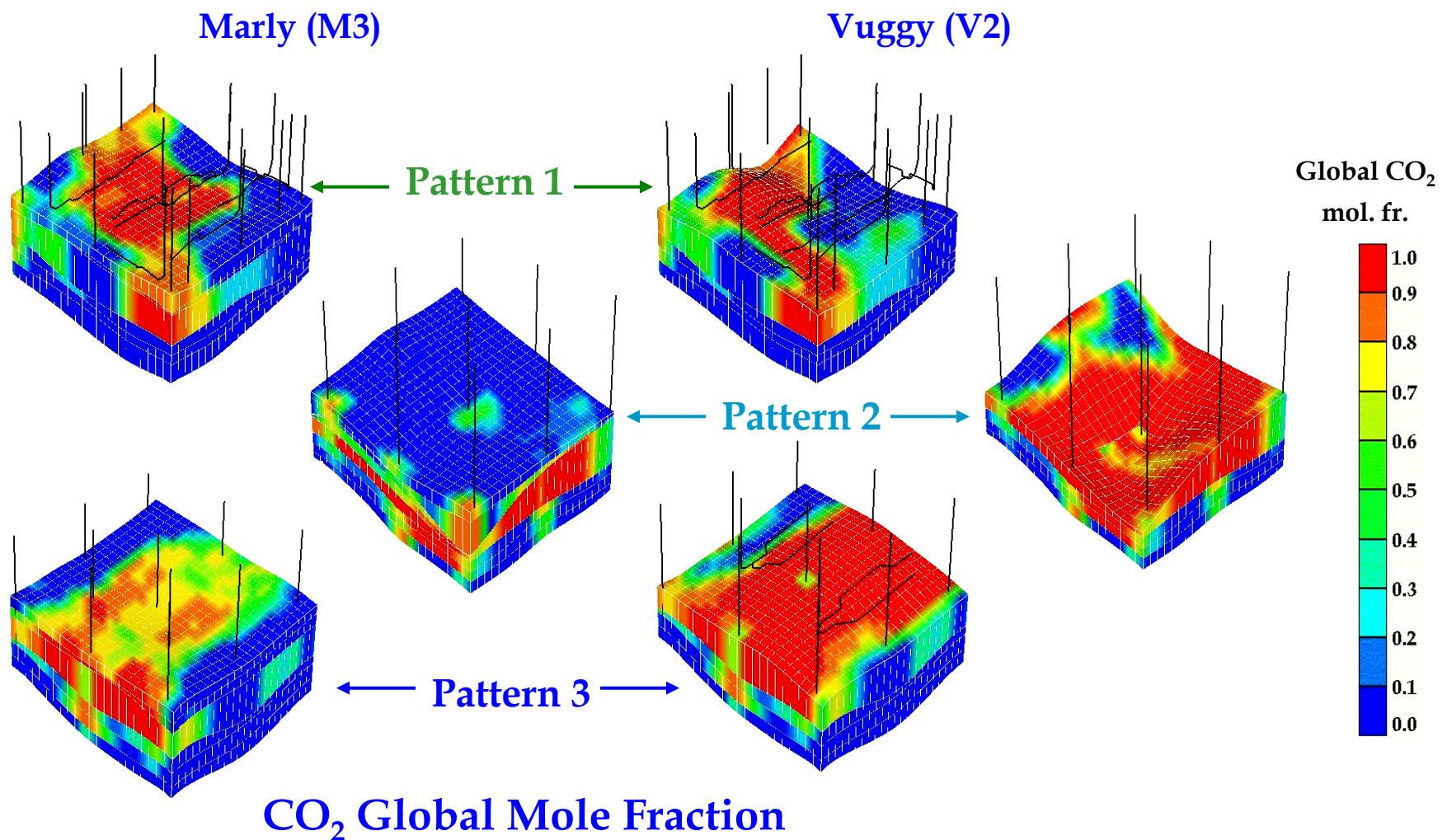
Prediction of CO₂ Distribution



Pattern 1 (SSWG): Case I

Prediction of CO₂ Distribution

End of CO₂-EOR (2025/01/01): Case I

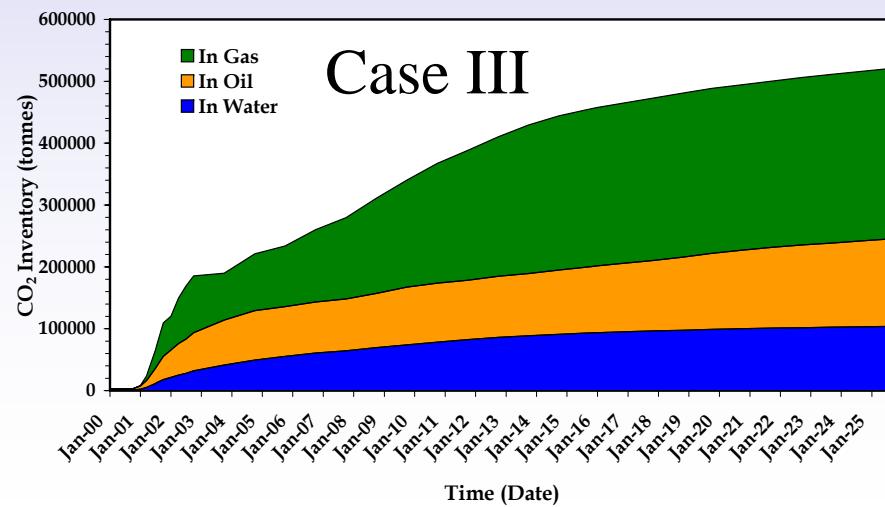
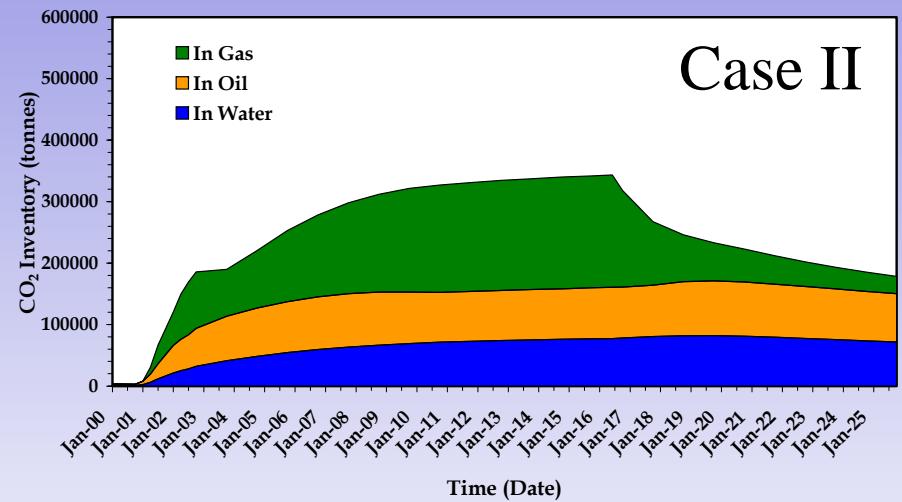
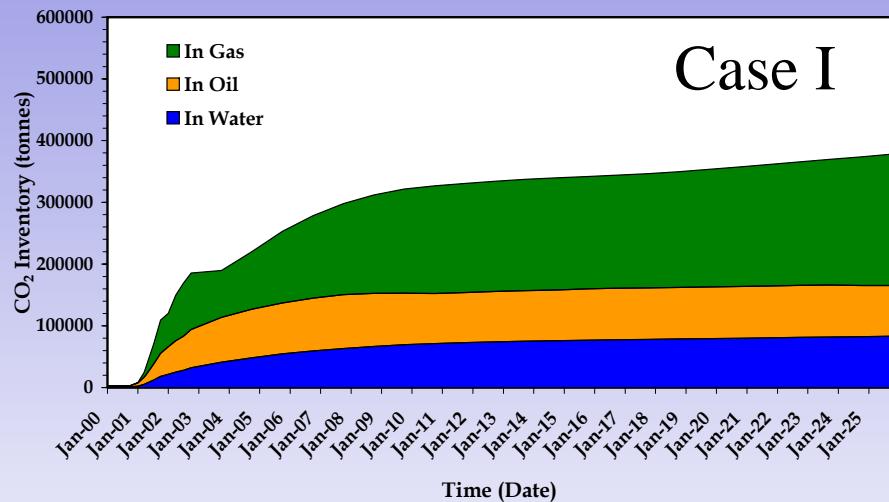


CO₂ Distribution and Storage Capacity

Pattern 1 (SSWG)

	<i>Pattern 1 - SSWG</i>		
	Case I	Case II	Case III
	CO₂ Inventory (tonnes) @ 2025/01/01		
In Gas	212,750 (56.3%)	28,036 (15.7%)	275,630 (52.9%)
In Oil	82,286 (21.7%)	78,813 (44.2%)	141,950 (27.2%)
In Water	83,080 (22.0%)	71,524 (40.1%)	103,940 (19.9%)
Total	378,116	178,373	521,520
Recycled	~ 80.7%	~ 85.7%	~ 60.5%
	Total Oil Recovery (%) OOIP – 2,535,010 m³		
Primary + Waterflood	34.7% (@ 2000/09/01)		
CO ₂ -EOR (Additional)	55.6% (20.9%)	54.1% (19.4%)	54.6% (19.9%)

CO_2 Inventory Pattern 1 (SSWG)



CO₂ Distribution and Storage Capacity

Pattern 2 (VWAG)

	<i>Pattern 2 - VWAG</i>		
	Case I	Case II	Case III
	CO₂ Inventory (tonnes) @ 2025/01/01		
In Gas	69,998 (40.0%)	34,359 (25.3%)	42,244 (30.6%)
In Oil	47,997 (27.5%)	46,458 (34.2%)	48,326 (35.0%)
In Water	56,832 (32.5%)	54,904 (40.5%)	47,402 (34.4%)
Total	174,827	135,721	137,972
Recycled	~ 76.3%	~ 79.2%	~ 53.4%
	Total Oil Recovery (%) OOIP – 1,313,887 m³		
Primary + Waterflood	32.2% (@ 2000/09/01)		
CO ₂ -EOR (Additional)	41.3% (9.0%)	40.6% (8.3%)	38.2% (5.9%)

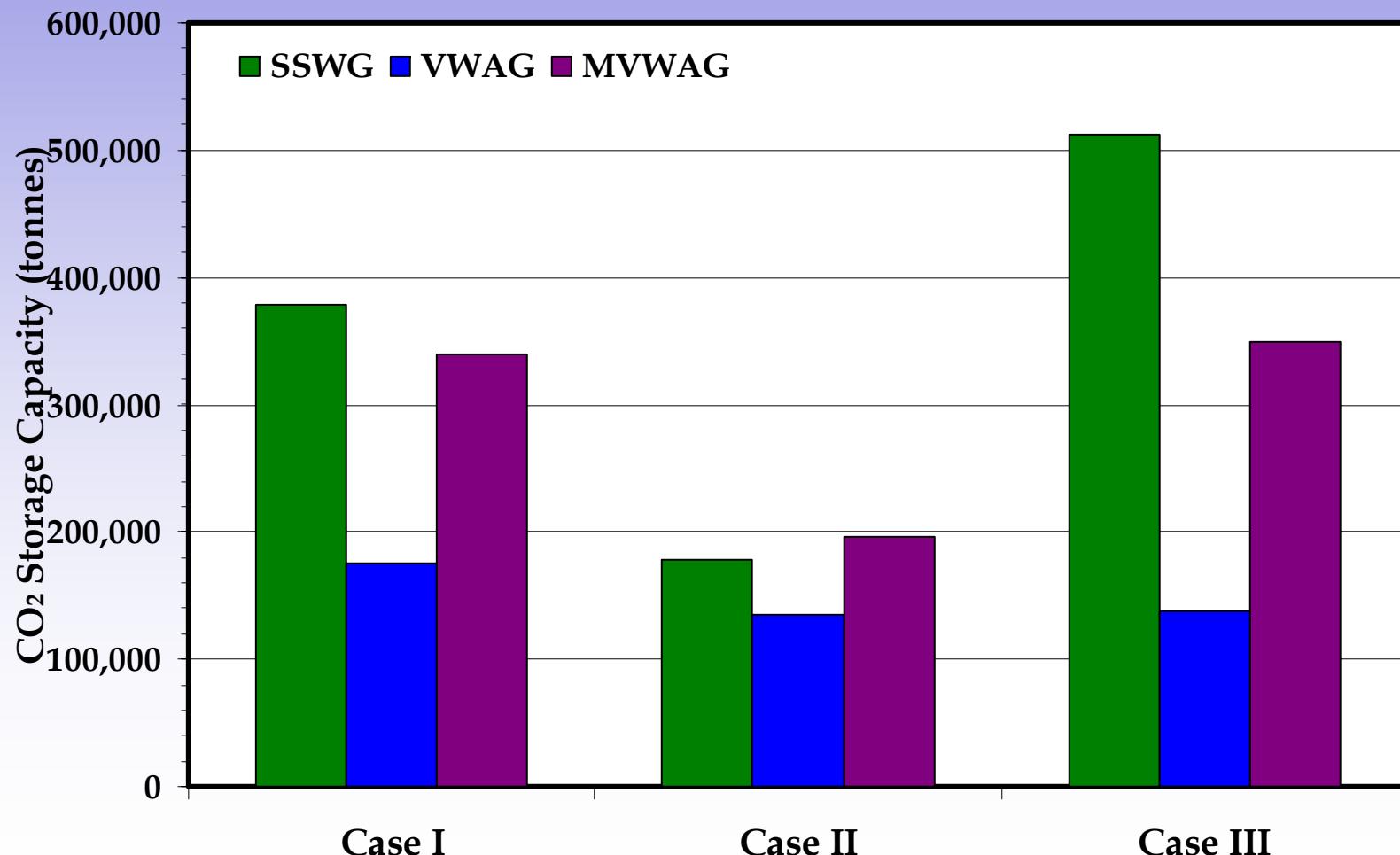
CO₂ Distribution and Storage Capacity

Pattern 3 (MVWAG)

	<i>Pattern 3 - MVWAG</i>		
	Case I	Case II	Case III
	CO₂ Inventory (tonnes) @ 2025/01/01		
In Gas	158,570 (46.6%)	36,017 (18.3%)	144,600 (41.3%)
In Oil	94,350 (27.7%)	91,316 (46.5%)	121,140 (34.6%)
In Water	87,286 (25.7%)	69,079 (35.2%)	84,197 (24.1%)
Total	340,206	196,412	349,937
Recycled	~ 80.7%	~ 83.1%	~ 60.7%
	Total Oil Recovery (%) OOIP – 1,736,165 m³		
Primary + Waterflood	29.1% (@ 2000/09/01)		
CO ₂ -EOR (Additional)	50.8% (21.7%)	48.3% (19.2%)	47.2% (18.1%)

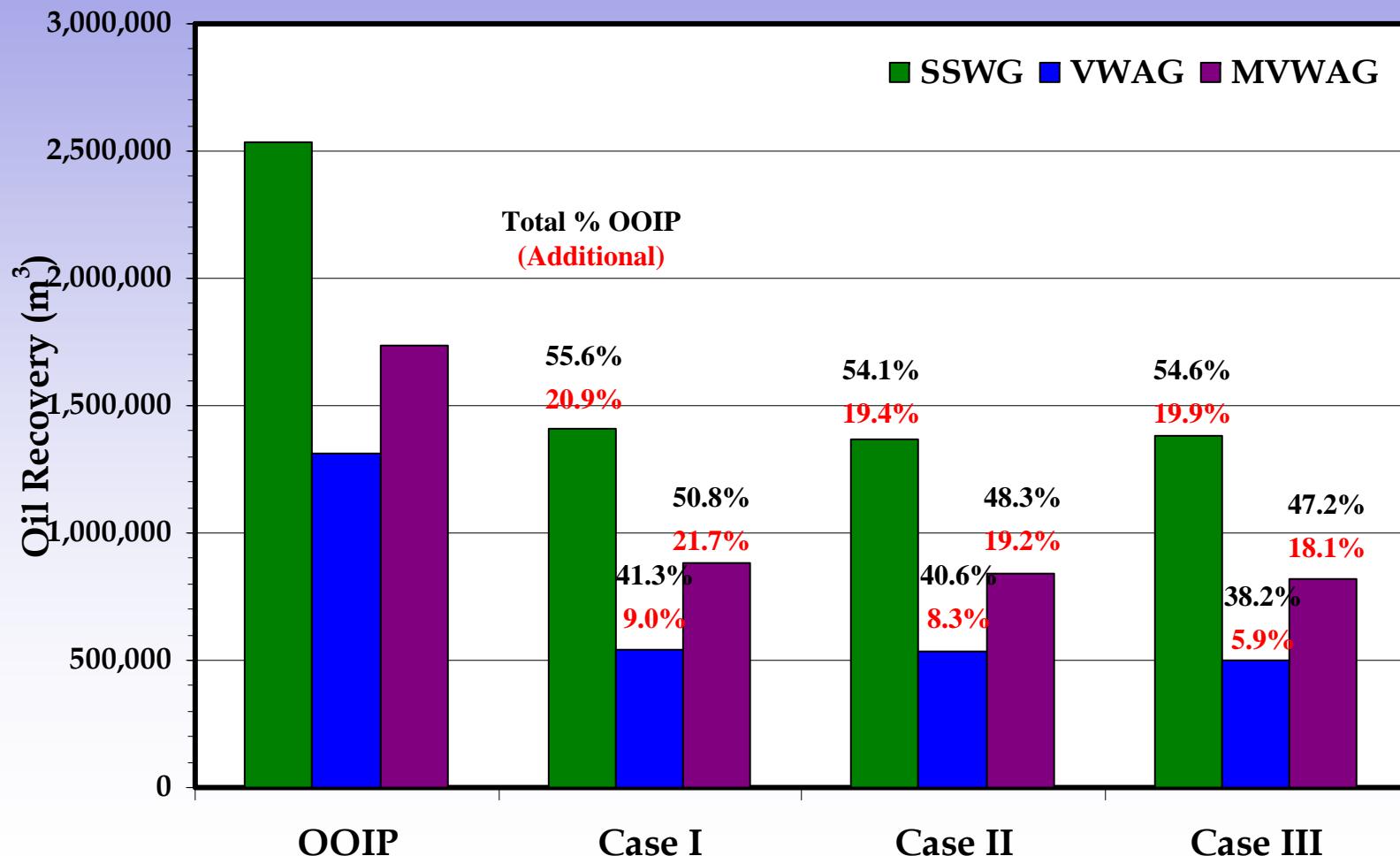
CO_2 Storage Capacity

Patterns 1, 2 and 3



CO_2 -EOR Performance

Patterns 1, 2 and 3



Conclusions

Patterns 1, 2 and 3

- CO₂-EOR/storage performances differed considerably, depending on CO₂ injection strategies
- In general, oil recovery response was faster in the SSWG patterns and CO₂ storage performance was also better, due to more CO₂ being injected from the horizontal injector
- For a given CO₂ injection strategy, oil recovery performance is less sensitive in the three operating cases investigated
- It is estimated that CO₂ storage in the order of 10⁵ tonnes can be achieved in each individual 320-acre pattern

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QUESTIONS ?

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